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Canada Centre for Mineral and Energy Technology
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FULL WAVEFORM ANALYSIS AT KIDD CREEK MINE - PROGRESS REPORT

L. LAVERDURE AND M. PLOUFFE

ELLIOT LAKE LABORATORY

MRL 91-104 (TR) Aug. 1991

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FULL WAVEFORM ANALYSIS AT KIDD CREEK MINE - A PROGRESS REPORT

L. Laverdure* and M. Plouffe**

ABSTRACT

A three-component geophone linked to a portable seismograph was installed at Kidd Creek Mine, Timmins, to register the seismic energy released during rockburst activity. Two hundred and eleven seismic events were collected over a forty-four day survey. The recorded waveforms will be analyzed later.

Because the results obtained by the source location program developed by CANMET are questionable, it was decided that both CANMET and Kidd Creek Mines would verify their respected systems. After accurate source locations are determined, rockburst related parameters such as the peak particle velocity (ppv), peak particle acceleration (ppa), energy, and attenuation will be evaluated.

Key words: Seismicity; Rockbursts; Waveform analysis.

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ANALYSE DES ONDES A LA MINE KIDD CREEK - RAPPORT D'ETAPE

L. Laverdure* et M. Plouffe**

RESUME

Un géophone triaxial relié à un séismographe portatif a été installé à la mine Kidd Creek, Timmins, afin d'enregistrer l'énergie séismique relachée lors de coups de toit. Les ondes des deux cent onze événements séismiques enregistrées durant quarante-quatre jours seront analysées.

Les résultats obtenus par le programme de localisation des sources développé par CANMET étant problématiques, il a été convenu que Kidd Creek et CANMET vérifieraient leurs systèmes respectifs. Après avoir obtenu des localisations précises, différents paramètres reliés aux coups de toit tels que la vitesse maximale de la particule (vmp), accélération maximale de la particule (amp), énergie et atténuation seront évalués.

Mots clés: Séismicité; Coup de toit; Analyse des ondes.

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INTRODUCTION

At the request of Kidd Creek Mine, Falconbridge Ltd., and after discussion with Dr. Thiann Yu, Chief Engineer, Research and Development, on February 20 1991, and CANMET it was agreed to carry out a feasibility study related to the monitoring of mining induced seismicity at the Kidd Creek Mine. CANMET proposed to collect and analyze the full waveforms for a period of approximately two months. The cost of the initial study was to be borne by CANMET. The present document is a progress report on this study up to July 1991.

INSTRUMENTATION

For this study, a portable battery operated seismograph, PDAS-100, from Teledyne Geotech was used. The instrument is shown in Figure 1.

The instrument uses 3 channels, each channel corresponding to the (x,y,z) orientation of the 3-component sensor. A 400 Hz digital and a 200 Hz analog antialias filter were installed in the PDAS. In addition, a 0.01 Hz low-cut filter was used to remove the DC offset.

The preamplifier gain was set at 10 for each of the 3 channels, and the low gain full scale input was set at $\pm$2.0 volts. The triggering level required some adjustments (as described later). The seismograph was set to trigger when the signal was greater than 6% of the input scale, i.e., $\pm$0.12 volt. Every event was recorded over a 3 second window. The data acquisition system records a 16-bit signal, with a sampling rate of 1000 samples/sec.

A 3-component piezoelectric ceramic geophone was used, in which x, y and z correspond to the north, east, and elevation coordinates, respectively. The polarity of the signals from the sensor are positive for a compressional wave going from west to east, from south to north, and from mine level to surface. The geophone response was flat between 0.02 and 2000 Hz. These accelerometers are effective between $\pm$2 g and are calibrated to read 5

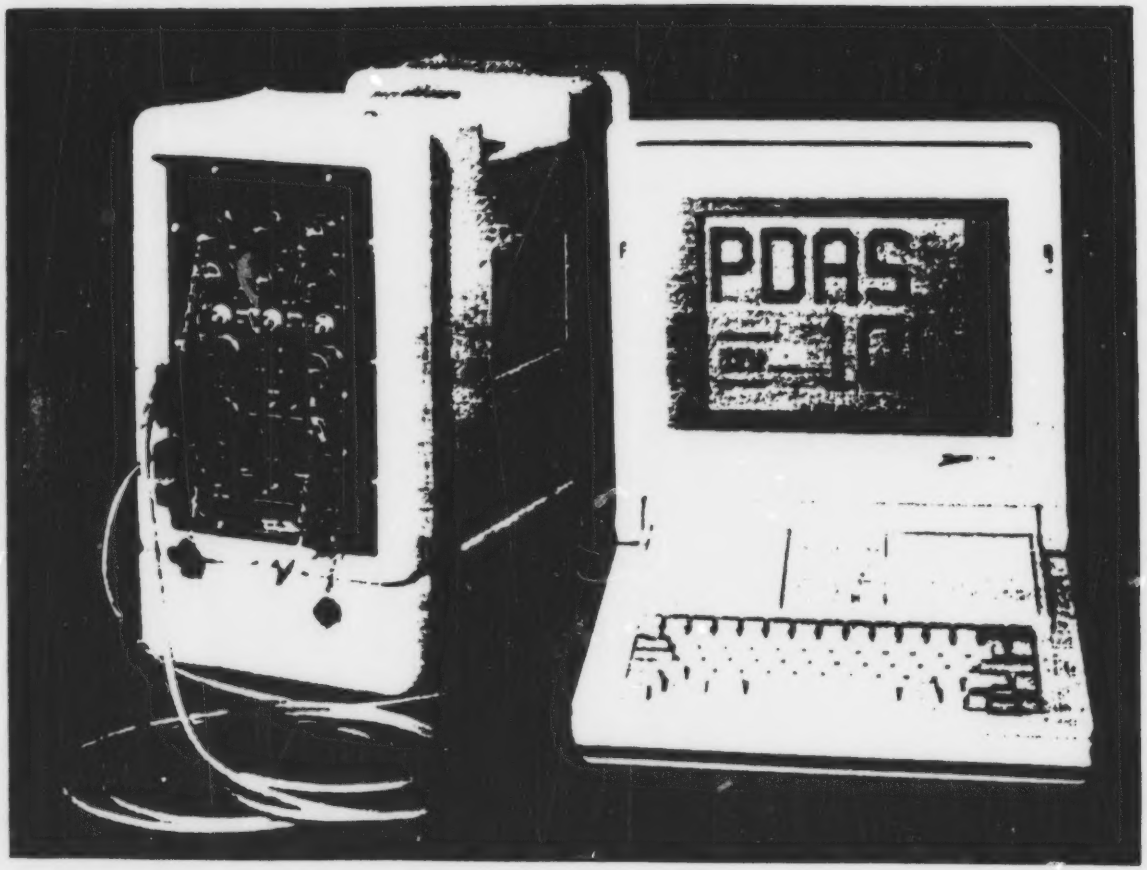

Fig. 1 - Three-channel PDAS-100 portable seismograph, and computer for data management.

volts/g, where g is the gravitational acceleration of 9.8 m/sec^2. The conversion factor between the amplitude and the acceleration was 0.00011963 m/sec^2.

The PDAS memory was accessed through the KERMIT communication software installed on any IBM-PC compatible.

Kidd Creek staff transfered the data from the PDAS memory to diskettes which were regularly sent to CANMET's laboratory in Elliot Lake. A procedure was provided to Kidd Creek in order to accomplish this task (Appendix A).

LOCATION

The PDAS was installed in a lunch room on the 800 level (Figure 2). The sensor's coordinates (x,y,z) correspond to the mine north, east, and elevation, respectively. In other words the x accelerometer is parallel to the lunch room and the y is perpendicular to it.

The instrument was set on a concrete floor near an electrical outlet. The battery pack turns on automatically if a power failure occurs.

TRIGGER LEVEL

When the instrument was installed the trigger level was set to 2.5% of the 2 V full scale voltage, i.e., $\pm$0.5 volts. As the PDAS memory filled up within a couple of days the trigger level was raised to 10%. Because of high trigger level no events were recorded during the following days. Finally, the trigger level was set at 6% which caused the memory to fill up during two weeks of data collection. This triggering level was maintained for the remainder of the experiment.

DATA COLLECTION

The first two diskettes received contained data collected from March 5, 1991, onwards. Six more diskettes were subsequently received from Kidd Creek.

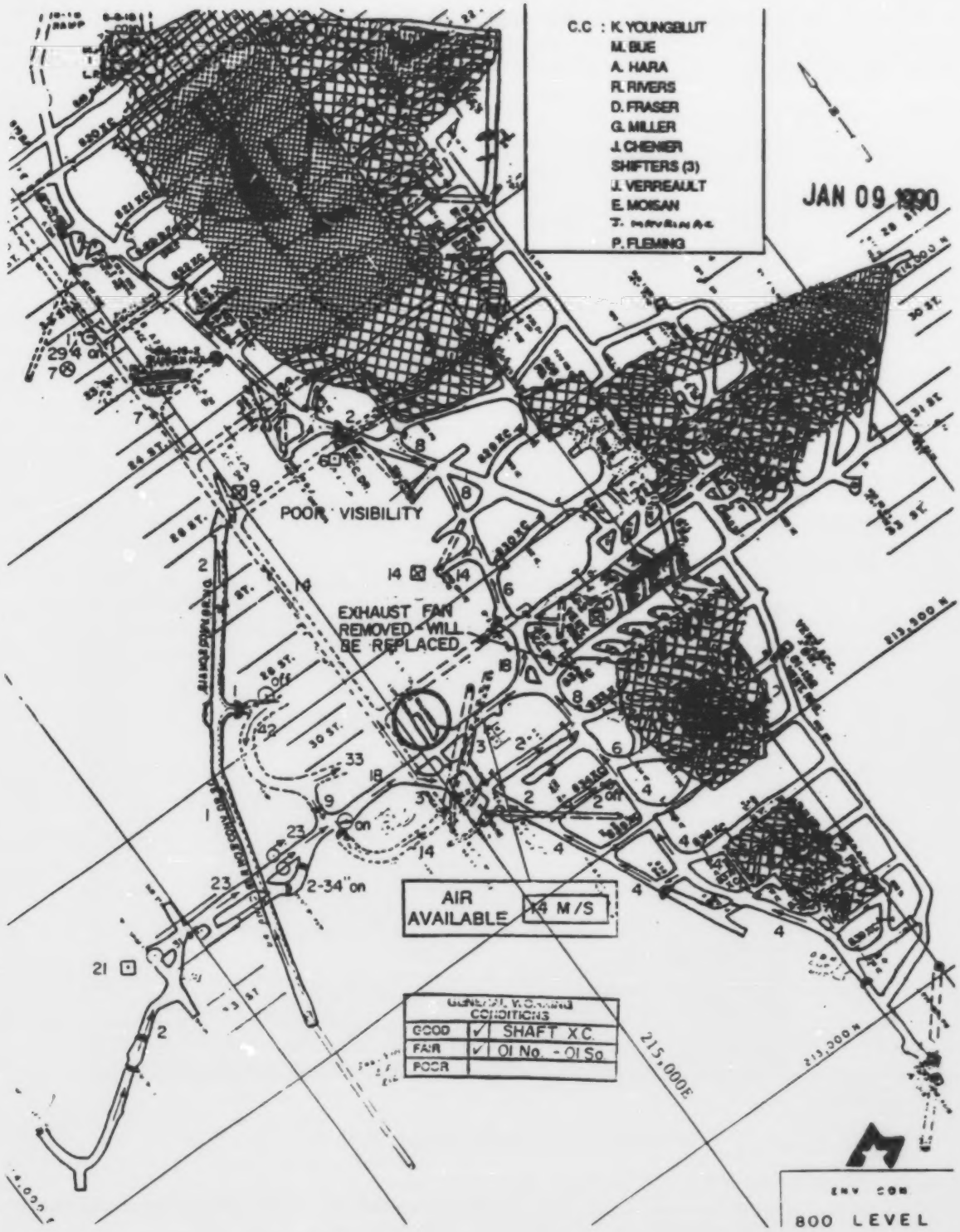

Fig. 2 - The location of the seismograph installed 800 level.

No events were collected between March 8, 1991 and May 3, 1991. This was caused by trigger level adjustments and computer problems related to the downloading of data. However, both problems were resolved in due course.

Over the period of study, 211 seismic events were recorded during the 44 days of recording March 5, 1991 to July 2, 1991. The number of days in each month, when data was collected is shown in Table 1.

Table 1 - Number of days per month of data collection.

Month	No. of days
March	3
April	0
May	17
June	22
July	2

From the events recorded, 23 events were selected for full waveform analysis (Table 2), while the others were classified as blast or ambient noise.

One of the events was a 2.6 magnitude rockburst which was recorded by the National Seismograph Network on June 27, 1991. Unfortunately, this event was not recorded and analyzed by the MP-250 system because of a power failure at the mine prior to the occurrence of the rockburst.

DATA ANALYSIS

The first step for data analysis was the selection of mining induced seismic events. After receiving the channel sequences which indicated the order in which the MP-250 geophones detected an event and the geophone location, a source location analysis was carried out.

Kidd Creek uses a USBM source location program attached to the MP-250 system (1). This program provides an approximate estimate of the source

Table 2 - The selected mining induced events.

Month	Day	Time*
March	06	11:51:49
	06	22:48:31
	07	00:54:00
May	03	23:38:00
	04	00:15:51
	21	22:54:45
	23	21:32:15
	24	04:56:08
	29	22:54:44
June	07	19:47:12
	12	22:43:40
	13	01:31:37
	17	23:27:16
	18	22:54:44
	19	02:34:59
	19	02:39:21
	19	02:48:02
	26	11:07:46
	27	04:29:31
	27	12:18:34
	28	23:41:40
	29	09:20:12
	30	10:35:16

*Time recorded by PDAS.

location, assuming that all arrival times of the channel sequence are produced by P-waves. Generally, P-waves carry less energy than S-waves and therefore attenuate faster (Figure 3). This implies that any MP-250 channel could be triggered by a shear wave. Moreover, any kind of noise (human, electrical, mechanical, etc.) could trigger the system. The program written by CANMET allows the interpreter to select the P, S, and noise channels independently. A change for P- and S-wave velocity for each travel path could also be studied. The BBLOCK program (3) is very flexible and produces a highly accurate source location (Appendix B).

The CANMET BBLOCK program was calibrated using dynamite blasts in different mines. The resolution of the source location is dependent on many factors, such as the geophone array, P-and S-wave velocity variations throughout the mine, and the distance between the source and the receivers. With a good array, the blasts could be located to within 10 feet (4).

In the case of Kidd Creek, it proved to be very difficult to obtain satisfactory source locations. Two main hypotheses could explain this situation. First, the results of the velocity measurements study (5) at Kidd Creek showed great variability. In order to reduce the large error (between the calculated and measured arrival times) engendered by constant P- and S-wave velocities, a velocity model was tried on each geophone for some of the selected events (Appendix B). However, it was not possible to correlate these velocity models with the geology because the related mining and geological maps were not available. In addition, in the past some source location problems have been related to wiring mismatch between the geophones and the data acquisition system and/or the mislocation of the geophones.

To identify problems related to the source location, Kidd Creek Mine agreed to verify: 1) all the (x,y,z) geophone coordinate locations, and 2) the wiring between the geophones and the MP-250. Up to now only one of 54 geophones was found to be misplaced by about 40 feet (6). CANMET also

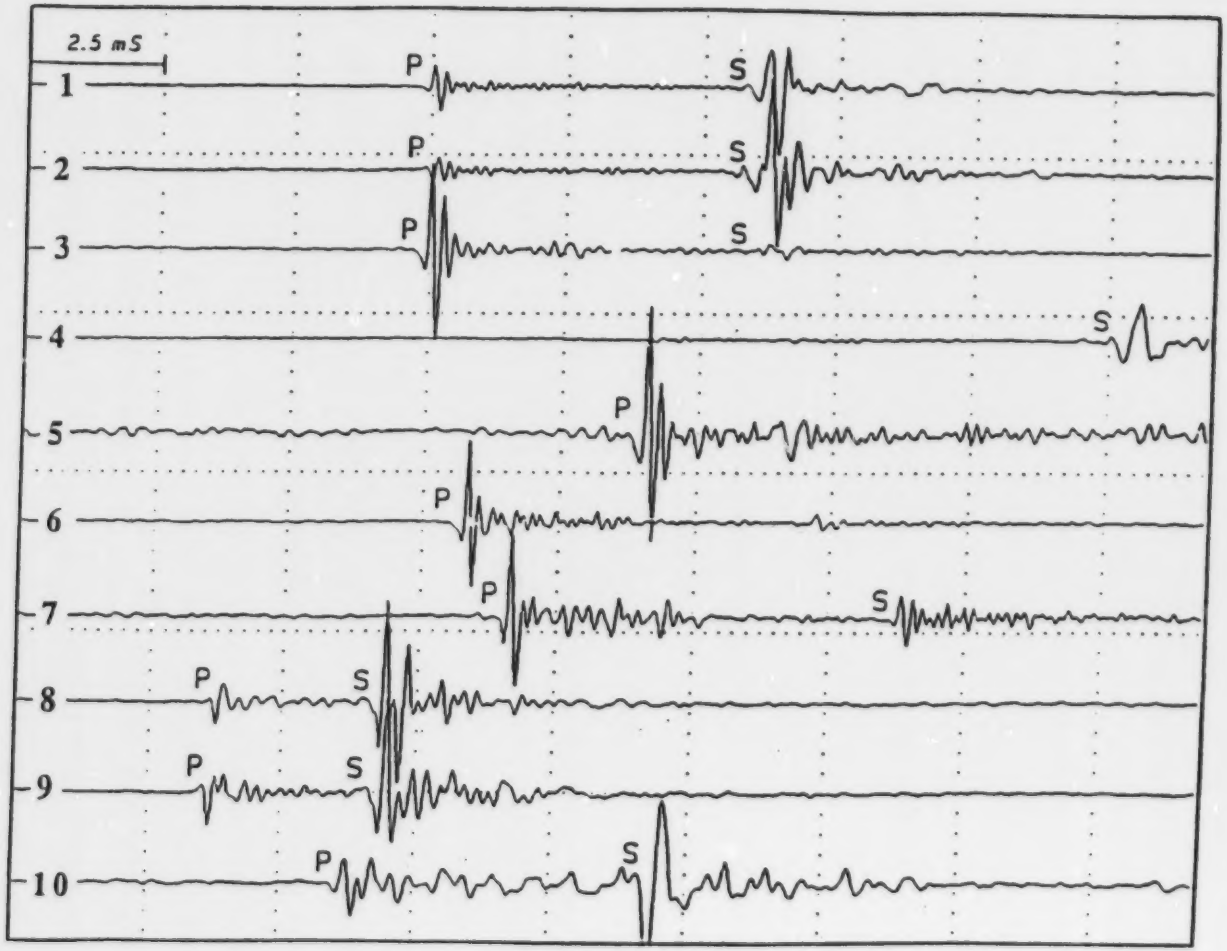

Fig. 3 - Recordings showing compression waves (P), and shear waves (S) (Talebi and Young, 1989).

requested the MP-250 channel sequence and the coordinates of a blast. These data will be analyzed with BBLOCK, and the source location will be compared with the blast locations in order to prove the validity of the procedure.

Because an accurate source location is necessary to execute a good waveform analysis it was agreed that CANMET would proceed with the analysis, depending on the submission of an additional proposal by CANMET. The improvement in the source location algorithm as mentioned at the meeting of August 1, 1991, would provide the necessary data for an accurate waveform analysis to be conducted on the data collected at Kidd Creek. For the June 27 event, although it is possible to arrive at an approximate solution based on a constant velocity model and wave polarity a more accurate evaluation will be obtained after a statistical analysis (7); after an accurate location has been obtained waveform analysis will proceed. Meanwhile, digitization of the mine plans has been undertaken and will continue. On such digitized mine plans the backfilled areas, the stopes, the drifts and the geophone array will be plotted. Examples of digitized mine plans are illustrated in Figures 4 and 5. The main geological units will also be added to such digitized mine plans depending on the computer resources.

FUTURE ANALYSIS

After receiving accurate source locations for the events shown in Table 2, the project will proceed as previously agreed. Similar to the other studies undertaken with the same instrumentation, e.g., Creighton mine (8), this study in time and frequency domains will include: peak particle velocity and acceleration, energy, attenuation, seismic moment and focal mechanism.

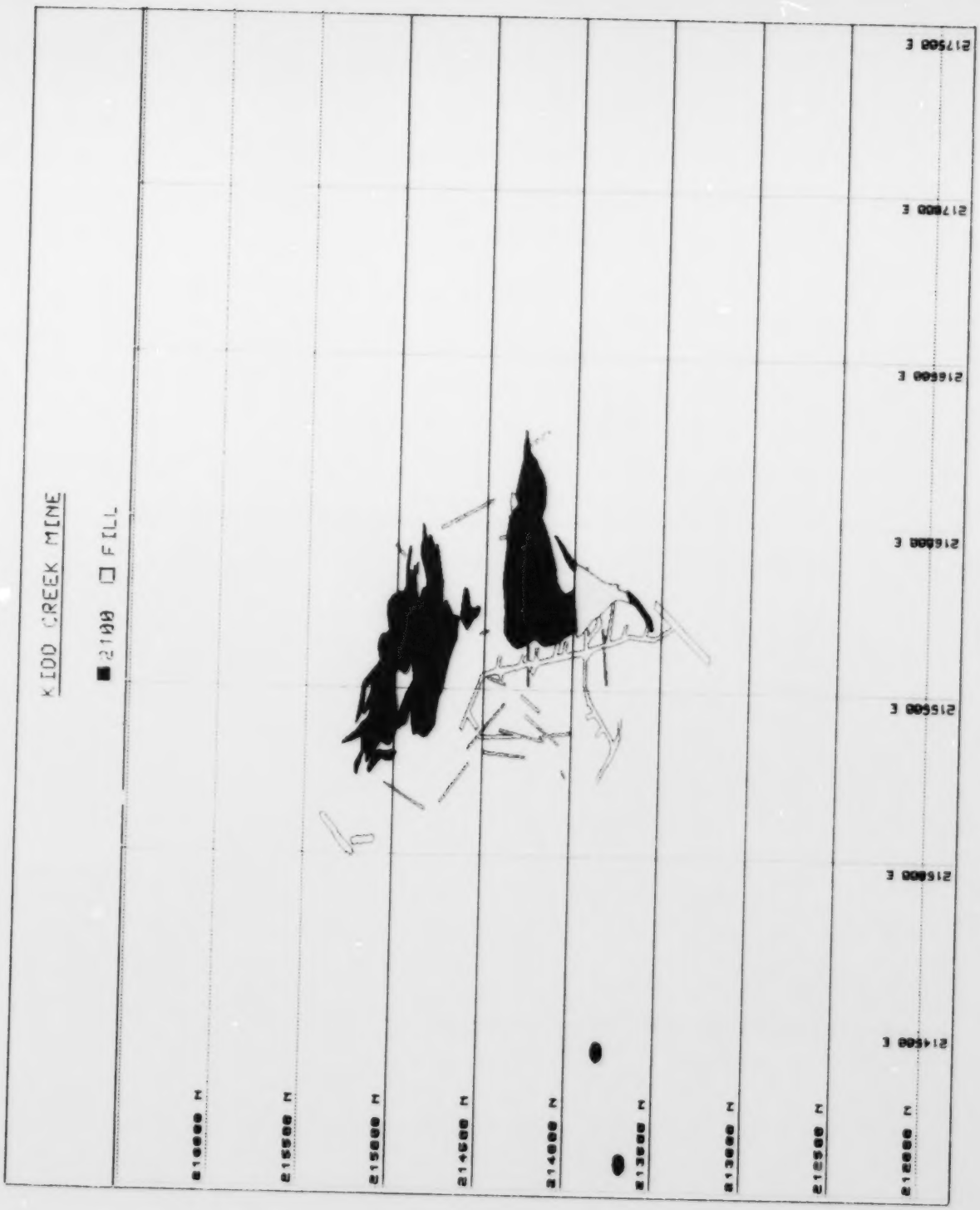

Fig. 4 - Example of digitized mine plan, 2100 level.

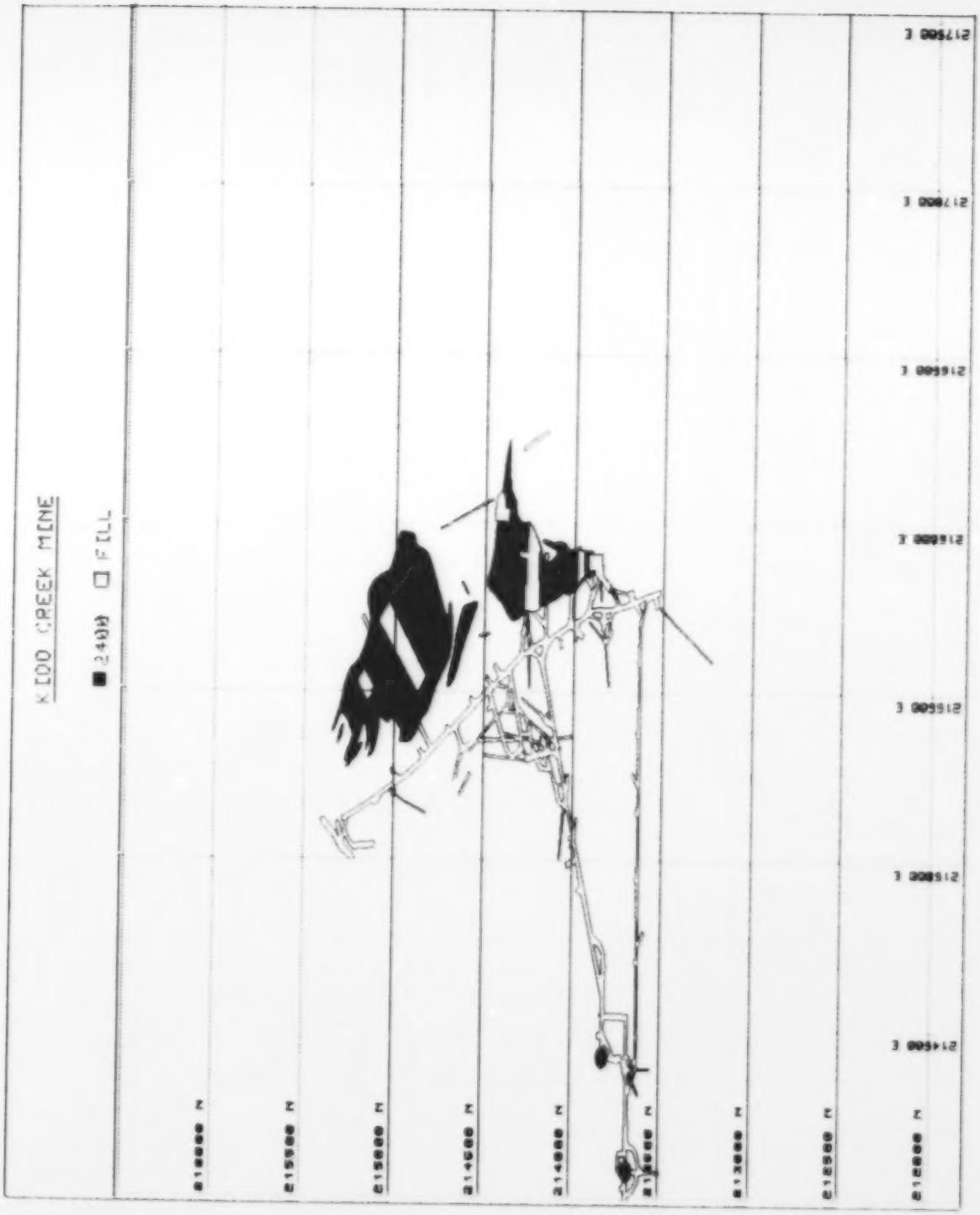

Fig. 5 - Example of digitized mine plan, 2400 level.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Yu and Mr. Disley of Kidd Creek Division for their assistance and cooperation.

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Appendix A - Data downloading procedure

Procedure to download the seismic data from the PDAS

A) download the data on a diskette
B) restart the acquisition mode

A) How to transfer the data from the seismograph PDAS to the computer's diskette

1) Connect the PARANET cable in the PRINTER output on the PDAS
in the printer output on the computer

2) Connect the SERIAL cable in the PSAC output on the PDAS
in the serial output on the computer

3) Turn on the computer

4)

5) Start PDAS

6) Press any key to start

7) Press <F2> to communicate with PDAS
You are now in the data acquisition mode
Press <Ctrl E>. The prompt should be C:\PDAS

8) Type pslave2 <Enter>

9) Press <Ctrl]>
Press c
Press q <enter>

10) Press <F6>

11) Press <F2>. You should see all the files being transferred. When this procedure is over press any key to continue.

12) Press <Esc> to return to the main menu

13) Press <F2> to communicate with PDAS. You are now in the slave mode. Type Q (N.B. Capital Q). You should see on the screen C:\PDAS (same as step 7)

14) Type cd\ch1
Type delete *.*
Type cd\ch2
Type delete *.*
Type cd\ch3
Type delete *.*
Type cd\pdas

To delete existing data files, on PDAS

15) <Ctrl]>
<c >
< q > <enter>

To get out of PDAS computer

16) Press <Esc> to get out of PDAS software.

B) How to restart the acquisition mode of the seismograph PDAS

1) Turn off and then on the "Power switch" on the PDAS.

2) Make sure that the acquisition mode of the PDAS is on. This is indicated by the regular flicking of the LED (diag).

3) Turn off the "Display Power" switch in order to save the batteries.

4) Turn off the computer.

5) Disconnect the PARANET and the SERIAL cables from the PDAS. Put back the caps on the PDAS plugs. Disconnect the same cables from the computer.

6) Now you only have to send us the data diskettes. Thank you.

Louise Laverdure
CANMET, MRL
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P.O. Box 100
Elliot Lake, Ontario
P5A 2J6

7) If you have any problem, you can reach us at:

Michel: (705) 461-7010
Louise: (705) 461-7019

Appendix B - Source location with BBLOCK

```
     EVENT:  EV  JD YR  TIME          BLOCK INCREMENT   VELOCITY
               1  65 91 11:51                  10.      19500.-11000.
                        66136      66239        2663
     BEST FIT AT:    X= 66148   Y= 66251   Z=   2675
                        66161      66264        2688
                   CH  11 CH  33 CH  31 CH  19 CH  12 CH  18 CH
ACTUAL EVENT          0   1955   3055   3200   3555   8385
BLOCK  EVENT          0.  4372.  3449.  3674.  3949.  7120.
CHANNELS OUT ARE : 33
"S" WAVE CHANNELS ARE :  33 31 19 12 18
     ERROR ERS        =    80.4
```

```
     EVENT:  EV  JD YR  TIME          BLOCK INCREMENT   VELOCITY
               2  65 91 22:49                   5.      23000.-12000.
                        65869      65526        2638
     BEST FIT AT:    X= 65878   Y= 65532   Z=   2647
                        65882      65539        2651
                   CH   8 CH  31 CH  25 CH  29 CH  19 CH  26 CH   9 CH  17
ACTUAL EVENT          0    600    725    750    980   1195   1525   1865
BLOCK  EVENT          0.   606.   599.   671.   574.  1392.  1757.  1801.
                   CH  11 CH  33 CH  12 CH
ACTUAL EVENT       1895   1975   2130
BLOCK  EVENT       1622.  1939.  1311.
CHANNELS OUT ARE : 19 12
"S" WAVE CHANNELS ARE :  26  9 17 11 33 12
     ERROR ERS        =    21.4
```

```
     EVENT:  EV  JD YR  TIME          BLOCK INCREMENT   VELOCITY
               3  66 91  0:52                  10.      19500.-11000.
                        65570      66694        2283
     BEST FIT AT:    X= 65588   Y= 66706   Z=   2295
                        65595      66719        2308
                   CH  31 CH  29 CH  22 CH  18 CH  16 CH
ACTUAL EVENT          0   2125   8455   9075   9470
BLOCK  EVENT          0.  3909.  8053.  8439.  8677.
"S" WAVE CHANNELS ARE :  29 22 18 16
     ERROR ERS        =   115.1
```

```
     EVENT:  EV  JD YR  TIME          BLOCK INCREMENT   VELOCITY
               3  66 91  0:52                  25.      15000.-11000.
                        65850      66325        1300
     BEST FIT AT:    X= 65900   Y= 66400   Z=   1375
                        65950      66425        1400
                   CH  31 CH  29 CH  22 CH  18 CH  16 CH
ACTUAL EVENT          0   2125   8455   9075   9470
BLOCK  EVENT          0.  2095.  8404.  9087.  9505.
YOU HAVE ENTERED YOUR OWN VELOCITY FOR EACH GEOPHONE
     ERROR ERS        =     4.1
```

```
     EVENT:  EV  JD YR  TIME        BLOCK INCREMENT   VELOCITY
              3  66 91  0:52              25.      20000.-11000.
                      65850     66350      1325
     BEST FIT AT:  X= 65875  Y= 66425  Z=  1400
                      65950     66450      1425
                CH  31 CH  29 CH  22 CH  18 CH  16 CH
ACTUAL EVENT         0   2125   8455   9075   9470
BLOCK  EVENT         0.  5526.  8433.  9088.  9521.
CHANNELS OUT ARE : 29
"S" WAVE CHANNELS ARE :  29 22 18 16
     ERROR ERS       =     3.6

WARNING: YOU HAVE ONLY  4 GEOPHONES IN YOUR SEQUENCE




     EVENT:  EV  JD YR  TIME        BLOCK INCREMENT   VELOCITY
              4 123 91 22:36              10.      21000.-10000.
                      65793     65397      2486
     BEST FIT AT:  X= 65805  Y= 65403  Z=  2504
                      65818     65422      2511
                CH  35 CH  26 CH  32 CH  20 CH  33 CH  36 CH  10 CH  19
ACTUAL EVENT         0    200    825   1150   1280   1345   1895   1900
BLOCK  EVENT         0.   166.   877.  1380.  1286.  1123.  1865.  1749.
                CH  12 CH  21 CH  31 CH  25 CH
ACTUAL EVENT      1905   1985   2180   2325
BLOCK  EVENT      1939.  1440.  1648.  1683.
CHANNELS OUT ARE : 21 31 25
"S" WAVE CHANNELS ARE :  32 20 33 36 10 19 12 21 31 25
     ERROR ERS       =    13.0


     EVENT:  EV  JD YR  TIME        BLOCK INCREMENT   VELOCITY
              4 123 91 22:36              10.      21000.-10000.
                      65793     65397      2486
     BEST FIT AT:  X= 65805  Y= 65403  Z=  2504
                      65818     65422      2511
                CH  35 CH  26 CH  32 CH  20 CH  33 CH  36 CH  10 CH  19
ACTUAL EVENT         0    200    825   1150   1280   1345   1895   1900
BLOCK  EVENT         0.   166.   877.  1380.  1286.  1123.  1865.  1749.
                CH  12 CH  21 CH  31 CH  25 CH
ACTUAL EVENT      1905   1985   2180   2325
BLOCK  EVENT      1939.  1440.  1648.  1683.
CHANNELS OUT ARE : 21 31 25
"S" WAVE CHANNELS ARE :  32 20 33 36 10 19 12 21 31 25
     ERROR ERS       =    13.0



     EVENT:  EV  JD YR  TIME        BLOCK INCREMENT   VELOCITY
```

```
              8 141 91 21:54                  10.      19000.-11000.
                       65218      64844        2464
     BEST FIT AT:   X= 65224   Y= 64862   Z=  2482
                       65243      64869        2489
                CH  19 CH  25 CH  31 CH  26 CH  33 CH  32 CH  20 CH   9
ACTUAL EVENT         0    480    935   1075   1335   2175   2850   2980
BLOCK  EVENT         0.   493.   791.   842.  2367.  2616.  2802.  3155.
                CH  17 CH  10 CH  11 CH   8 CH
ACTUAL EVENT      3630   4365   4370   4600
BLOCK  EVENT      3328.  4272.  3187.  4635.
CHANNELS OUT ARE : 33 11
YOU HAVE ENTERED YOUR OWN VELOCITY FOR EACH GEOPHONE
     ERROR ERS       =    26.8


     EVENT:   EV  JD YR  TIME        BLOCK INCREMENT   VELOCITY
              8 141 91 21:54                  25.      20000.-12500.
                       64775      64750        2875
     BEST FIT AT:   X= 64825   Y= 64800   Z=  2925
                       64875      64850        2975
                CH  19 CH  25 CH  31 CH  26 CH  33 CH  32 CH  20 CH   9
ACTUAL EVENT         0    480    935   1075   1335   2175   2850   2980
BLOCK  EVENT        97.   239.   316.   272.      0.   394.  3151.  3437.
                CH  17 CH  10 CH  11 CH   8 CH
ACTUAL EVENT      3630   4365   4370   4600
BLOCK  EVENT      3527.  4362.  3116.  4473.
CHANNELS OUT ARE : 31 26 33 32 11
"S" WAVE CHANNELS ARE :  20  9 17 10 11  8
     ERROR ERS       =    36.1


     EVENT:   EV  JD YR  TIME        BLOCK INCREMENT   VELOCITY
              9 141 91 21:54                  10.      20000.-12000.
                       65908      65485        1771
     BEST FIT AT:   X= 65920   Y= 65503   Z=  1789
                       65933      65510        1796
                CH  32 CH   9 CH  29 CH  35 CH   8 CH  10 CH  20 CH  31
ACTUAL EVENT         0    410    965    990   2560   2680   2945   2965
BLOCK  EVENT         0.   764.  1015.   938.  2355.  2295.  2974.  2779.
                CH  36 CH  18 CH  14 CH   1 CH
ACTUAL EVENT      4110   4495   5040   5440
BLOCK  EVENT      4134.  4399.  5173.  5708.
YOU HAVE ENTERED YOUR OWN VELOCITY FOR EACH GEOPHONE
     ERROR ERS       =    32.5


     EVENT:   EV  JD YR  TIME        BLOCK INCREMENT   VELOCITY
             10 143 91 20:31                  10.      20000.-12000.
                       66993      65611        3394
     BEST FIT AT:   X= 67005   Y= 65623   Z=  3406
                       67018      65636        3419
```

```
                CH   7 CH  29 CH   6 CH   4 CH  14 CH  16 CH   2 CH  18
ACTUAL EVENT      0    485   1185   1665   2080   2205   5900   9100
BLOCK  EVENT      0.   511.  1378.  1531.  2019.  2612.  6055.  8783.
YOU HAVE ENTERED YOUR OWN VELOCITY FOR EACH GEOPHONE
     ERROR ERS      =    31.1



     EVENT:  EV  JD YR  TIME        BLOCK INCREMENT   VELOCITY
             11 144 91  3:55              10.      20000.-12000.
                     65398     64766      3444
     BEST FIT AT:  X= 65410  Y= 64778  Z=  3456
                     65423     64791      3469
                CH   7 CH   6 CH   4 CH  14 CH  16 CH   2 CH  18 CH  15
ACTUAL EVENT      0   1295   1630   2095   2205   2860   4540   5195
BLOCK  EVENT      0.  1197.  1487.  2128.  2287.  3009.  4507.  5144.
YOU HAVE ENTERED YOUR OWN VELOCITY FOR EACH GEOPHONE
     ERROR ERS      =    13.9



     EVENT:  EV  JD YR  TIME        BLOCK INCREMENT   VELOCITY
             12 144 91 17:55              10.      20000.-12000.
                     65156     65764      2870
     BEST FIT AT:  X= 65168  Y= 65782  Z=  2882
                     65181     65789      2895
                CH   9 CH  11 CH  19 CH  25 CH   0 CH   8 CH  31 CH  23
ACTUAL EVENT      0    490   1790   1895   1900   2070   2135   2635
BLOCK  EVENT      0.   410.  1834.  1884.  1668.  2159.  1942.  2494.
                CH  29 CH  32 CH  10 CH   4 CH
ACTUAL EVENT    2645   2875   3350   3520
BLOCK  EVENT    2318.  3291.  3789.  3216.
YOU HAVE ENTERED YOUR OWN VELOCITY FOR EACH GEOPHONE
     ERROR ERS      =    31.1



     EVENT:  EV  JD YR  TIME        BLOCK INCREMENT   VELOCITY
             13 149 91 21:54              10.      20000.-12000.
                     64907     64366      3823
     BEST FIT AT:  X= 64919  Y= 64378  Z=  3835
                     64932     64391      3848
                CH   2 CH   4 CH  15 CH   7 CH   0 CH  12 CH   9 CH   1
ACTUAL EVENT      0    260    940   4300   5455   6640   6700   7520
BLOCK  EVENT      0.   305.   835.  4389.  5346.  6261.  6643.  7610.
                CH  20 CH  19 CH  11 CH   8 CH
ACTUAL EVENT    7905   7945   8010   8280
BLOCK  EVENT    7924.  8319.  7496.  8701.
YOU HAVE ENTERED YOUR OWN VELOCITY FOR EACH GEOPHONE
     ERROR ERS      =    30.2
```

```
     EVENT:  EV  JD YR  TIME          BLOCK INCREMENT   VELOCITY
             14 149 91 21:54                  10.      20000.-12000.
                       67557      65930       2581
     BEST FIT AT:   X= 67569   Y= 65942   Z=  2587
                       67582      65955       2606
                 CH  30 CH   1 CH   0 CH   3 CH  13 CH  10 CH   5 CH  31
ACTUAL EVENT          0    925   3470   3755   4910   5455   5795   7020
BLOCK  EVENT          0.   836.  3335.  3958.  4612.  5671.  5746.  7151.
                 CH   4 CH  23 CH  32 CH  14 CH
ACTUAL EVENT       7410   8045   8555   8670
BLOCK  EVENT       7255.  8077.  8210.  9002.
YOU HAVE ENTERED YOUR OWN VELOCITY FOR EACH GEOPHONE
     ERROR ERS       =    25.3
```

```
     EVENT:  EV  JD YR  TIME          BLOCK INCREMENT   VELOCITY
             15 149 91 21:54                   5.      21000.-11000.
                       66357      65506       2643
     BEST FIT AT:   X= 66363   Y= 65515   Z=  2649
                       66370      65519       2656
                 CH   1 CH   0 CH   3 CH  10 CH  13 CH   5 CH  30 CH   9
ACTUAL EVENT          0    370    535   1535   1885   2775   3490   4140
BLOCK  EVENT          0.   418.  2705.  2071.  2126.  2271.  3138.  4074.
                 CH  23 CH  32 CH  31 CH  29 CH
ACTUAL EVENT       4265   4935   6115   6335
BLOCK  EVENT       3606.  3365.  3902.  4016.
CHANNELS OUT ARE :  3 23 32 31 29
"S" WAVE CHANNELS ARE :   3 10 13  5 30  9 23 32 31 29
     ERROR ERS       =    38.5
```